LOCKING BONE PLATE

Background of the Invention

This invention relates to devices, implants and prostheses used in orthopedic surgery, and, more particularly, to bone plates used to reinforce fractured bones and thus promote healing.

A compressive screw system, also known as the DCS system, is a bone plate system that has been used in trauma surgery for many years. The procedures for use of this system are well documented by the AO Institute, an institute having as one of its goals, the promotion of new orthopaedic surgical procedures. This system included a bone plate having slots communicating therethrough. A land in which the slot is wider at one end defines a stepped surface adjacent the portion of the slot that extends through the bone plate. The stepped surface is generally cut with a spherical endmill, thus creating a spherical stepped surface.

In a still further development, bone plates have been developed having individual threaded apertures and non-threaded apertures interspersed along the length of the plate. In this and other designs, the distance between holes has become a standard. Although an improvement over the inserts noted above, the locking positions are pre-defined, and only available in limited locations, which also reduce surgical flexibility. In another product variation, expandable, lockable inserts enter into the slots of a standard bone plate. When the bone screw passes through one of these inserts and is torqued down, the insert expands and locks the screw in place. However, this insert is locked in a secondary operation. This is not desirable because this requires more operating room time and adds complexity to the procedure. Further, the inserts must be added in the specific location before the plate is fixed to the bone and cannot be subsequently inserted. This limits the choice of placement during surgery if the need arises.

Also, the above insert design relies on a friction lock via contact between two surfaces. Friction locks are not reliable and come lose more easily than threaded locked holes. The result of such a design is inferior to that of the threaded plate and screw designs discussed below.

In US Patent 5,002,544 to Klaue et al, there is shown an osteosynthetic pressure plate having a cross-section transverse to the longitudinal axis of the plate at at least one point being wider toward the upper surface than toward the lower surface and the plate having recesses in the lower surface so that upon application to a bone there is space between the bone and the plate. The cross-section between the screw holes is reduced, preferably to the extent that the resistance of the plate to bending in this area is less than in the area of the holes. Because of the reduced bend resistance between the holes, the plate can more easily be adapted to conform to the anatomy of the bone. Furthermore, this can be done without deformation of the holes, thus minimizing the resulting loss of fatigue strength and minimizing the misfit of the screw heads.

Further, US Patent No. 5,709,686 to Takos et al describes a bone plate that has recesses or

reduced thickness portions on its sides, between threaded apertures. Although the purpose is not specifically described, these recesses appear to function to avoid warpage of the threaded portions when the bone plate is bent. However, when such a bone plate is fixed to a bone, these discontinuous recesses are exposed and may potentially come into contact with and potentially aggrevate muscle tissue.

Still further, US Patent No. 5,733,287 to Tepic et al shows (in figure 4), a plate that has transverse cuts 13 and a longitudinal cut 14 on the lower surface 7 to reduce contact between the plate and bone. Due to the transverse undercuts 13, the cross-section 15 between the holes is already significantly reduced and therefore is not further decreased by an additional groove 10 on the upper surface 6 as in the embodiment according to figure 3. To avoid a cross-section that is too thin, the groove 10 on the upper surface 6 is made discontinuous in short segmental grooves 16 providing a smooth transition into and out of the holes 8.

In yet another solution, PCT application no. WO01/54601 combines the features of the DCS system discussed above with a locking screw. This design combines the features of the DCS system with a locking screw. Such a system is known as the combi-slot. In this design, the stepped surface of the slot is generally ramped or tapered so as to be deeper at one end than at another. This enables the positioning and selective fixing of the bone plate for compressing two bone fragments together with a preload created by wedging action. In this manner, the bones are placed in a position that the surgeon believes would best promote healing.

Further, this combi-hole includes two distinct overlapping portions in a single slot. One portion of the slot is suited to receive a standard bone screw, while the other portion of the slot is suited to receive a threaded peg oriented perpendicular to the top surface of the bone plate. Also, the combi-holes are generally oriented with the threaded portions being on the innermost end of the combination and the unthreaded portions oriented toward the ends of the bone plate. This improvement increased the flexibility of choice available to orthopaedic surgeons using the device in that it was more likely that a hole would be present at a suitable anchoring point in the bone plate. Nevertheless, there are often trauma situations that are best served by the threaded portion being at the extreme ends of the bone plate and/or at various positions throughout the plate. In addition, sometimes there is no specific center of the facture –in such a situation, use of the combi-hole design is limited.

While patent application no. WO01/54601 has proven advantageous because screws can be locked to the plate, the presence of an unthreaded slot limits the users ability to have multiple orientations for the screw.

In a further development, the AO Institute has studied and proposed the use of endpegs which are rigidly fixed in the extreme ends of the bone plate. Such an arrangement has been shown to better resist the flexing of the bone than use of a bone screw alone. Flexing can otherwise loosen the connection

between the bone plate and bone in other bone plate systems.

In another development, German patent DE 4341980 A1, published on June 14, 1995, describes a bone plate 2 having an elongated slot 8 in which the sidewalls of the long sides of the slot are not parallel and are further provided with an internal thread 9. Corresponding bone screws 3 or inserts 6 have a head 5 with an external taper 4 and thus can be fixed into any point along the length, but to various depths of penetration. Therefore, the final configuration upon fixing is indeterminate and, due to the small amount of contact between the threads of the insert or screw and the slot, as well as the fact that the screw will be able to slide in one direction, the design does not appear to lend itself to reliable fixing.

US Patent No. 5,324,290 shows a complex bone plate having slots with countersunk circular recessed cut at intervals along the slot (a similar arrangement is shown in US Patent No. 4,696,290). It further shows the bone plate torqued against the bone so as to at least marginally, conform to the shape of the bone (see Fig. 2). Other patents of interest include US Patent No. 3,716,050, 3,659,595, 5,681,311, 5,261,910, and 5,364,399, all showing combinations of conventional slots and recesses which do not fully accommodate a bone screw having a threaded head.

In comparison with the combi-hole design and the friction locking design described above, what is needed is a bone plate that provides greater flexibility of choice to the surgeon. More specifically, what is needed is a bone plate that provides this choice of plate placement while reliably and permanently fixing the bone plate to the bone fragments, in any hole position.

What is needed is a bone plate that provides greater flexibility of choice to the surgeon, in a bone plate that has multiple orientations for the locking screw and thus, plate placement, while reliably and permanently fixing the bone plate to the bone fragments, in any hole position.

In addition, what is needed is a versatile bone plate having recesses which determine where the bone plate will bend, in order to avoid the threads in any holes to be bent or warped, while maintaining a smooth external surface.

Finally, what is needed is a bone plate with holes that create bi-directional compression.

Summary of the Invention

A bone plate is provided having a longitudinal axis, a bone-contacting bottom side and a top side. Sets of overlapping holes communicate through the plate from the top to the bottom side. The overlapping holes have multifaceted surfaces such as a threaded surface or a coaxial series of annular grooves. The sets of overlapping holes are adapted to receive a bone screw with a head and a bone-engaging thread.

An object of the invention is to provide an orthopaedic surgeon greater flexibity of choice in that a threaded peg providing secure fixing can be positioned at any interval along the bone plate, including at

its extreme ends.

Brief Description of the Drawings

FIG. **1a** is a perspective view of a bone plate in which the overlapping holes align along a longitudinal axis of the bone plate.

FIG. **1b** is a top plan view of a bone plate in which the overlapping holes align along a longitudinal axis of the bone plate.

FIG. **1c** is a longitudinal cross-sectional view of a bone plate in which the overlapping holes align along a longitudinal axis of the bone plate.

FIG. **1d** is a top plan view of a single set of overlapping holes.

FIG. **2a** is a perspective view of a set of two overlapping holes having a threaded surface.

FIG. **2b** is a perspective view of a set of two overlapping holes in which the surface of each hole is a coaxial series of annular grooves.

FIG. **3** is a longitudinal cross-sectional view in which some of the overlapping holes are formed normal to the top side of the plate.

FIG. **4** is a longitudinal cross-sectional view in which all the overlapping holes are formed at an angle offset from normal to the top side of the plate.

FIG. **5** is a top plan view of a bone plate in which the overlapping holes are staggered along a longitudinal axis of the bone plate.

FIG. **6a** is a top plan view of the bone plate showing a set of three overlapping holes.

FIG. **6b** is a longitudinal cross-sectional view showing the sets of three overlapping holes in which all holes are aligned normal to the top surface of the bone plate.

FIG. **6c** is a longitudinal cross-sectional view showing the sets of three overlapping holes in which some of the holes are aligned normal to the top surface of the bone plate.

FIG. **6d** is a longitudinal cross-sectional view showing the sets of three overlapping holes in which all holes are aligned at an angle offset from normal to the top surface of the bone plate.

FIG. **7a** is a plan view of an orthopaedic kit of the invention including a case, a bone plate, a variety of bone screws, and threaded pegs of various lengths.

FIG. **7b** is a perspective view of an orthopaedic kit of the invention including a case, a bone plate, a variety of bone screws, and a drill guide.

FIG. **8** is a side view of a bone screw having a head and a bone-engaging thread.

FIG. **9a** is a perspective view of an alternate embodiment of the bone plate having lower recesses.

FIG. **9b** is a second perspective view of the alternate embodiment of the bone plate.

FIG. **9c** is a side view of the alternate embodiment of the bone plate.

FIG. **10a** is a perspective view of a second alternate embodiment showing lower recesses on the bone plate.

FIG. **10b** is a bottom view of the alternate embodiment of the bone plate.

FIG. **10c** is a side view of the alternate embodiment of the bone plate.

Detailed Description of the Preferred Embodiment

Referring now to FIGS. **1a** to **1d**, a bone plate 10 with a longitudinal axis 12 has a bone-contacting bottom side 14 and a top side 16. Multiple sets 20 of overlapping holes 22 communicate through the plate 10 from the top side 16 to the bottom side 14. The overlapping holes 22 are adapted to receive a bone screw 24 with a head 26 having a thread 30 and, on an opposite end 32, a body having a bone-engaging thread 34 (shown in FIG. **8**).

The multiple sets 20 of overlapping holes 22 allow for further adjustability and flexibility in positioning of the bone plate 10 during surgery. The overlapping holes 22 are formed normal to the top side 16 of the plate 10 (shown in FIGS. **1c** and **1d**).

Referring now to FIG. **2a** and **2b**, the overlapping holes 22 have multifaceted surfaces 36. In one embodiment, the multifaceted surface 36 is a threaded surface 40 (shown in FIG. **2a**). In another embodiment, the multi-faceted surface 36 is a coaxial series of annular grooves 42 (shown in FIG. **2b**).

Overlapping holes 22 are formed individually at an angle Ø offset from normal to the top side 16 of the plate 10. Such allows further flexibility of choice to the surgeon as to where and how to fasten the

bone plate 10. Referring again to FIGS. 1c and 1d, where these overlapping holes 22 are oriented perpendicularly to the top side 16 of the bone plate 10, he may chose to fasten the plates in a conventional manner, namely, perpendicular to the top side of the plate.

Referring now to FIG. 3, in a preferred embodiment, some of the overlapping holes 22 are formed normal to the top side 16 of the plate 10.

Alternatively, as shown in FIG. 4, all of the overlapping holes 22 are formed at an angle Ø offset from normal to the top side 16 of the plate 10.

Referring now to FIG. 5, the overlapping holes 22 may be formed offset from the longitudinal axis 12 of the bone plate 10, in a staggered manner.

Referring now to FIGS. 6a to 6d, in an alternate embodiment, the bone plate 10 may include sets 20 of three overlapping holes 22. Referring in particular to FIGS. 6b, where these overlapping holes 22 are oriented perpendicularly to the top side 16 of the bone plate 10, the surgeon may chose to fasten the plates in a conventional manner.

Referring in particular to FIG. 6c, in a preferred embodiment, some of the overlapping holes 22 are formed normal to the top side 16 of the plate 10.

Alternatively, as shown in FIG. 6d, all of the overlapping holes 22 are formed at an angle Ø offset from normal to the top side 16 of the plate 10.

Referring now to FIGs. 7a and 7b, in another embodiment, orthopaedic kits 44 are provided which include a case 46, a bone plate 10, a variety of bone screws 24, threaded pegs 50 of various lengths, and a drill guide 52. The drill guide 52 has a threaded end 54 that threads into the thread 40 of an overlapping hole 22. The drill guide 52 has a main drill guide surface 56 to securely hold the drill guide in a desired orientation with respect to the bone plate 10 in order to stabilize a drill (not shown) used in an orthopaedic procedure.

Referring now to FIGs. 9a – 9c, an alternate embodiment of the bone plate 10' is provided with lower recesses 60 of rectangular form, extending transversely across the bone plate. These recesses 60 are preferably positioned at regular intervals along the longitudinal axis, between threaded apertures 62. Such recesses 60 are provided in order to reduce the contact area between the bottom side 14 of the bone plate 10' and the bone, as well as to prevent bending of the bone plate across a threaded aperture 62 (thus preventing warping of the threads 36). The total area removed from the bottom side 14 due to the recesses 60 is preferably less than or equal to 25% of the total surface area of the bottom side.

The recesses 60 are substantially located exclusively on the bottom side 14 and are sized so as to define a cross-section 64 transverse to the longitudinal axis and across the recesses. This ensures that a yield strength in bending across the recesses 60 is less than across a threaded aperture 62 and thus, prevents damage of the threads upon forming of the bone plate to mate with a curvilinear surface of a bone.

Referring now to FIGs. 10a -10c, a second alternate embodiment of the bone plate 10" is shown having another form of lower recesses 66. These recesses 66 do not extend across the bottom side 14 of the bone plate 10", but rather extend from a side 70 of the bone plate a short distance toward the centerline 12 of the bone plate, but do not traverse the centerline.

Note that the threaded apertures 100 used in the invention provide hole centers located at specific locations (as opposed to apertures that are formed as a slot). Use of threads centered at a specific point allows the bone screw to be fixed at a specific location at which the surgeon may judge the bone structure to be best suited to support such a bone screw. Unlike designs using a slot, the apertures 100 of the invention eliminate wander of the screw in the aperture. This further permits placement at specific locations for buttressing and/or secure fixing in neutral screw loading areas.

In another feature, locking bone pegs (not shown) interface with the threaded apertures. The threads cut in the head of these pegs are designed so as to lock with the threaded apertures in order to better ensure rigid fixing of a fracture when using pegs having a body without threads. The locking feature used can be any of the known methods of locking threads by mechanical means.

In an advantage of the invention, the bone plate 10 provides greater flexibility of choice to the surgeon in that a threaded peg providing secure fixing can be positioned at any interval along the bone plate, including at its extreme ends.

In another advantage, the bone plate 10 provides greater flexibility of choice by providing multiple overlapping holes 22 oriented (1) along the longitudinal axis 12 of the bone plate, (2) oriented at an angle Ø to the longitudinal axis, and (3) staggered along the axis.

In still another advantage, the threaded apertures 40 of the bone plate 10 are provided with threads cut perpendicular to the top side 16 of the bone plate, as well as at an angle Ø to normal.

Multiple variations and modifications are possible in the embodiments of the invention described here. Although certain illustrative embodiments of the invention have been shown and described here, a wide range of modifications, changes, and substitutions is contemplated in the foregoing disclosure. In some instances, some features of the present invention may be employed without a

corresponding use of the other features. Accordingly, it is appropriate that the foregoing description be construed broadly and understood as being given by way of illustration and example only, the spirit and scope of the invention being limited only by the appended claims.